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EXPERIMENTAL ANALYSIS OF FORCED CONVECTIVE HEAT TRANSFER IN A PIN-FIN

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ABSTRACT

Extended surfaces or fins are used to increase the heat transfer rates from a surface to the surrounding fluid wherever it is not possible to increase the value of the surface heat transfer coefficient or the temperature difference between the surface and the fluid. The project emphasis on the performance of pin-fin based heat transfer analysis and it also describes the fabrication of pin-fin and venturimeter. The project involves use of venturimeter for measuring flow rate, centrifugal blower, thermostats and variac. The blower acts as source for forced convection, pin-fin is heated by an electrical heater. Thermocouples are mounted along the length of the fin for temperature measurement and the duct at the exit. Here at the exit a venturimeter is provided for flow rate measurement. By this experiment the efficiency and heat transfer coeffiecient of a pin-fin in forced convection is investigated.

Keywords: *Optical pyrometer, heat transfer coefficient, flow rate, forced convection*.

I. INTRODUCTION

Fins are surfaces that extend from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection or radiation an object determines the amount of heat it transfers. Increasing the temperature gradient between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer.

A.A.Warty, A.K.Prajapat,K.D.Yadav et.al **[**1**]** studied performance of pin fin of three different materials (Aluminium, Brass & stainless steel) is studied. The influence of design parameters like the pin fin length, diameter & fin material on thermal efficiency of the natural convection heat sink is evaluated using the experimental setup prepared by graphical programming language with Lab VIEW.

Karan Sangaj, Sudarshan Shinde et. al [2] have considered different shapes (rectangular, circular, tapered, conical, parabolic etc.) and different materials (copper, aluminum, mild steel, brass, stainless steel). Experiments have been conducted to find the temperature distribution within the pin fin made of different material and geometries and steady state heat transfer analysis has been carried using a finite element software ANSYS to test and validate results.

Allan Harry Richard.T.L et.al. [3] Carriedout experiment accomplished by using blower in the riser tube, which connects to the thermocouple which flows the air to the heater. From the heater the air gets heated and the air transfer to the the pin fin in it. This procedure followed for the fin of different materials, Reynolds number, Nusselts numbers are calculated and heat transfer coefficient and fin.

Sivashankar M et. al [4] The experiments were carried out by increasing the surface area of all proposed fins(13.86%,13.05%,32.59% respectively) compared to conventional fin. All the fins are placed on the heater which acts as a heat source and keeping air flow rate constant. The results showed that the fin efficiency for the proposed fin-3 increased by 12.39% compared to conventional fin.

Zaharaddeen Aminu Bello, Pankaj Rao [5] In the case of force convection, the heat transfer rate of circular is 1.128W with the effectiveness, efficiency, Nusselt number and Reynolds number of 31, 91%, 9.09 and 324.3 respectively. In the case of triangular pin fin the heat transfer rate is 0.685 with the effectiveness, efficiency Nusselt number and Reynolds number of46, 95.5%, 24.51 and 2720.81

G. Ganesh Kumar, B. Anil Kumar et. al [6] Different configurations like solid pin fin, hollow pin fin, solid pin fin with four equal perforations, solid pin fin with one large perforation, knurled fins, hollow fin with four perforations are considered for two different convective modes viz., free and forced convection. Various experimental results obtained from the experimental set up designed for the purpose. Detailed comparative studies were presented here.
Shnurr et. al [7] studied radiation from an array of longitudinal fins of the triangular profile arranged around a cylinder of isothermal base. The fins were considered to be infinitely long and base interaction was also considered. The effects of external incident radiation were ignored. The results were useful in optimizing the design for minimum weight.

Chung and Zhang et. al [8] presented a new approach to minimize the weight of radiating straight fin array. The effect of base interaction was considered and the fins were infinitely long. In this study the fins were arranged symmetrically around the circular tube. The temperature of the tubes surface was considered to be uniform both longitudinally and circumferentially.

Abdullah H. et al [9] describes about the enhancement of natural convection heat transfer from a Fin by triangular perforation of bases parallel end turned its tip. In this investigation the triangular perforation made in rectangular pin investigated with variable thickness of pin and this equals high compound with solid fin.

P. K. Nag and M. Ali [10] Nawsher Moral studied experimentally the effect of pin fins on heat transfer in circulating fluidized beds. It was observed that, although the heat transfer coefficient decreases with the use of fins, the total heat transfer increases owing to the increase in surface area which the fins provide. The results of heat transfer for unfinned surface were compared with those of other researchers and found to be in good agreement.

II. PURPOSE OF A FIN

To increase heat transfer by increasing the surface area without increase of primary surface area. FIN involves both (Conductive + Convective) Heat Transfer. Finally it loses heat to the atmosphere.

III. HEAT TRANSFER FROM FINNED SURFACES

The rate of heat transfer from a surface at a temperature Ts to the surrounding medium at T infinity is given by Newton' s law of cooling as,

$$\dot{Q}_{\text{conv}} = hA_s(T_s - T_\infty) \quad \text{.........} (1)$$

IV. FIN PERFORMANCE PARAMETERS

Fin performance is described in three different ways
(i) Fin effectiveness of a single fin
(ii) Fin efficiency of a single fin

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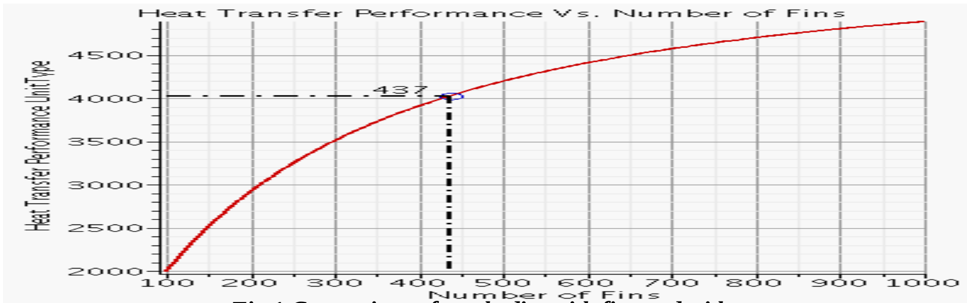

Fig 1 Comparison of two bodies with fins and without

V. FABRICATION OF PIN-FIN

Fabrication of pin-fin involves machining of pin-fin to transform that to required shape. Major alterations done to the pin-fin are reducing the diameter of the fin and obtaining good surface finish.


Fig 2(a) Top View of the Fin


Fig 2(b) Front view of the Fin

The operations to be performed on the lathe are facing and turning. Facing to obtain smooth faces which directly contribute to the efficiency of the fin. Turning is to reduce the diameter of the fin, which also adds to the effectiveness of the fin. By using turning the fin dia, which was 25mm was reduced to 16mm. And by facing the rough faces which were present at the start were smoothened out for good appeareances.

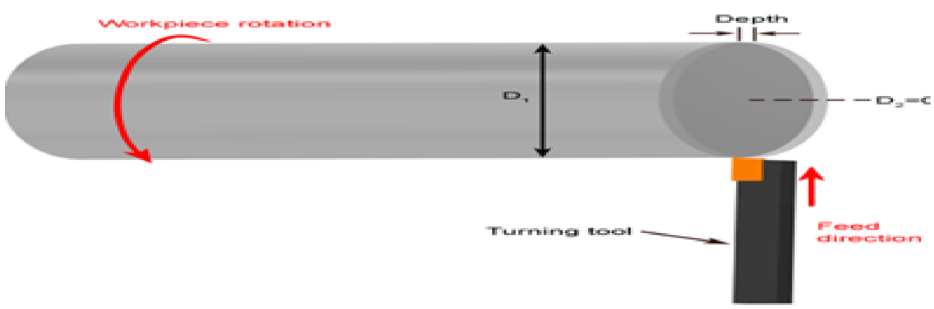

Fig 3 Turning Operation

VI. FABRICATION OF VENTURIMETER

Fabrication of the venturimeter is done by using G.I sheet for strength and durability. First G.I Sheet should be cut into appropriate size, the standard size is 210mm x 250mm.After cutting into standard size, mark the boundaries to cut the G.I sheet. First make the 3mm diameter on the sheet and then make the bigger hole of 8mm diameter hole on the sheet to avoid the bending of the sheet.

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Fig 4(a) GI sheet used

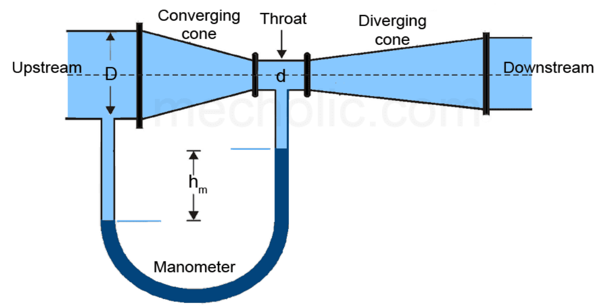

Fig 4 (b) schematic of the Venturimeter

Fig 5(a) Top view of the venturimeter

Fig 5 (b) Front view of the venturimeter

VII. EXPERIMENTAL PROCEDURE

Heat is conducted along the length of fin and also lost to surroundings. Applying first law of thermodynamics to a control volume along the length of fin at a station which is at length ‘x’ from the base

$$m=\sqrt{h\,P/KA}\,dX \quad \text{....(2)}$$

$$\text{Heat flow, 'q'} = \theta_0\sqrt{hc\,PKA}\;\tanh mL \quad \text{....(3)}$$

With the boundary conditions of θ = θ1 at x = 0, θ =θ2, T1-Tf Assuming tip is to be insulated, Temperature distribution along the length of the fin is

$$\frac{\theta}{\theta_0} \quad \frac{T-T_\infty}{T_o-T_\infty} = \frac{\cosh[m(L-x)]}{\cosh(mL} \quad \text{....(4)}$$

$$\Sigma = \theta_0 \sqrt{\frac{h\,PKA \tan h\, mL}{h\,A}} \quad \text{....(5)}$$

$$\Sigma = \sqrt{\frac{PK}{hA}}\;\tanh(mL) \quad \text{....(6)}$$

The efficiency of a fin is defined as the ratio of the actual heat transferred by the fin to the maximum heat transferred by the fin if the entire fin area were at base temperature.

$$\eta_f = \theta_0 \frac{h\,PKA \tan h\, mL}{h\,PL\theta_0} \quad \text{....(7)}$$

$$\eta_f = \tan h\, mL/mL \quad \text{....(8)}$$

This is the equation for temperature distribution along the length of the fin. Temperatures T1 and Tf will be known for the given situation and the value of 'h' depend upon mode of convection i.e. natural or forced. Heat transfer in pin A) Natural Convection Open the duct cover over the fin. Ensure proper ear thing to the unit and switch on the main supply. Adjust dimmer stat so that about 110 V are supplied to the heater. The fin will start heating. When the temperatures remain steady, note down the temperatures of the fin and duct fluid temperature. Sl. NO. INPUT Fin temperatures ^{o}C. Duct fluid temperature oC V I T1 T2 T3 T4 T5 T6 (Tf).

B) Forced Convection Close the duct cover over the fin. Start the blower. Adjust the dimmer stat so that about 100 – 110v are supplied to the heater. When the temperatures become steady, note down all the temperatures and manometer difference Calculations.

VIII. RESULTS AND DISCUSSIONS

Tm = Average fin temperature = (T1 + T2 + T3 + T4 +T5) /5 Tf– Tm =T Δ Tmf = Mean film temperature = (Tm+ Tf) / 2
ρa = Density of air, kg / m3
ρw = Density of water, kg / m3 = 1000 kg / m3
D = Diameter of pin fin Heat transfer in pin fin d = Diameter of venturimeter = 65 x 10-3 m
Cd = coefficient of discharge of orifice = 0.9
μ = Dynamic viscosity of air, N-s/m2 Cp = Specific heat of air, kJ/kg.K
ט =Kinematic viscosity, m2/s
Kair = Thermal conductivity of air, W/m K
β = volume expansion coefficient = 1 / (Tmf+273.15)
H = Manometer difference, m of water
V = velocity of air in duct, m/s
Q = volume flow rate of air, m3/s
Vtmf = velocity of air at mean film temperature

All properties are to be evaluated at mean film temperature. NATURAL CONVECTION The fin under consideration is horizontal cylinder losing heat by natural convection. For horizontal cylinder, Nusselt number, from data book, page number 122. Nu= 1.02 (Gr.Pr)0.148 ----------for 10-2 < Gr.Pr < 102

Nu = 0.85 (Gr.Pr)0.188 --------- for 102 < Gr.Pr < 104. Nu= 0.48 (Gr.Pr)0.25 ----------for 104 < Gr.Pr < 107 Nu = 0.125 (Gr.Pr)0.333 --------- for 107 < Gr.Pr < 1012. Where Gr = Grashoff number. .

Pr = Prandtl number = air k μCp. (take from data book.) Determine Nusselt number. Now, Nu = (hD)/kair Therefore, h = Nu. Kair /D From h determine m from equation (3), Using h and m, determine temperature distribution in the fin from equation (4) The rate of heat transfer from the fin and efficiency can be calculated as, Heat transfer in pin fin and h

P k =. . . ( ) fin f A T1 Tf Q mL tanh [mL] =η FORCED CONVECTION For flow across Horizontal cylinder loosing heat by forced convection, from data book, page number 100.

Nu = 0.911 (Re)0.385. Pr. 0.333 ---------- for 4 < Re < 40 Nu = 0.683 (Re)0.466 .

Pr. = 0.333 ---------- for 40 < Re < 4000, Nu= 0.193 (Re)0.618 .

Pr. = 0.333 ----------for 4000 < Re < 40,000 Where, ν V D R tmf

e. = (273). (273) ++= f mf tmf T V T V Velocity of air is determined from air volume flow.

Nusselt Number, find out ‘h’ and from ‘h’, find out ‘m’ Now temperature distribution, heat transfer rate and effectiveness of the fin can be calculated using equations 4, 5 and 6 respectively. From the results obtained it is found that ‘h’ under forced convection is 31.02W/m2K. Effectiveness of pin-fin is 37.087. Efficiency of finis 65.2%

Table 1 comparison of performance of brass and bronze fins

Properties	Bronze	Brass
Electrical conductivity	7.4	15.9
Thermal Conductivity (W/m.k)	8.5	6.3
Density (Kg/m3)	8.8	8.5
Melting point or degradation	1040	900
Thermal expansion coefficient.	17	20
Efficiency of the fin	65.2	79.726
Effectiveness of the fin	37.087	32.643

IX. CONCLUSIONS

Bronze is an alloy that consists primarily of copper with the addition of other ingredients.

In most cases the ingredient added is typically tin, but arsenic, phosphorus, aluminum, manganese, and silicon can also be used to produce different properties in the material.

All of these ingredients produce an alloy much harder than copper alone.

Bronze is characterized by its dull-gold color and we can also tell the difference between the brass and bronze by viewing the dull rings on the surface of bronze.

Bronze is an alloy consisting primarily of copper, commonly with about 12% tin, and often with the addition of other metals applications.

Bronze is used in the construction of sculptures, musical instruments and medals, and in industrial applications such as bushings and bearings, where its low metal on metal friction is an advantage. The overall electrical and mechanical properties of bronze is found to be comparatively better than brass.

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